# PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

## Improvements relating to the Measurement of Skid or Slip Resistance of Surfaces

We, THE PENNSYLVANIA STATE UNIVERSITY, of University Park, Pennsylvania, United States of America, (Assignee of HARTWIG W. KUMMER), an institution established by the legislature of the State of Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to apparatus for rapidly determining the skid or slip resistance of a surface under a standard loading condition.

Particularly in the field of highway safety specifications, it is desirable to measure and classify conditions of a road surface with respect to the degree of skid resistance which these surfaces present to the wheels of passing vehicles. Similarly, other surfaces such as factory floors which require anti-skid properties must be measured and classified to determine compliance with specifications or with safety standards. Various weather conditions may also make it important that a standard measurement be readily available for determining safe vehicle speed standards or liability for negligent use of the highway. Similar questions of liability may arise in connection with working and walking surfaces where a hazard is presented.

Means for measuring skid resistance or slipperiness of pavements have been known heretofore for use in the laboratory and for spot checking of isolated spots on a highway or other surface to be examined. A second type of skid resistance testing device is designed for use while travelling along a highway at relatively high speed. The laboratory-type measuring means, when adapted for use outside, involves detailed close inspection and the use of carefully adjusted pendulum measurements, and the like. The high speed trailer type of highway inspection device is generally not suitable for use in localized areas such as slippery spots associated with intersections and unusual positions of wear. Whenever it is necessary to make a measurement on a slope or a curve or to measure large areas where the laboratory measuring means is unsuitable and the high speed road inspection device cannot be used, a suitable direct-reading apparatus has not been previously available, nor have methods been known for rapidly determining the coefficient friction or the skid resistance.

According to the present invention, apparatus for measuring the skid or slip resistance of a surface comprising a housing supported at one end for movement over said surface, a friction shoe movably mounted on the other end of said housing for frictionally engaging the surface, means for applying a force to the housing in the proximity of said surface for moving said housing, a hydraulic system including a mechanism for resisting movement of the friction shoe relatively to the housing and converting a frictional force applied to said shoe into a hydraulic pressure, and a gauge hydraulically connected to said system so as to be responsive to said hydraulic pressure therein.

A preferred embodiment of the apparatus comprises a two-wheeled trolley having suspended from common rotational axis thereof one end of the housing which forms a load of predetermined magnitude, the other end of the housing being carried by the shoe which has a surface or edge bearing against the surface to be measured in accordance with a suitable loading factor. Skid resistance measurement is made by advanc-

ing the trolley in one direction by means of a handle so mounted that the trolley axle carries the supported end of the load smoothly at a position adjacent the surface. Movements of the handle are not permitted to exert substantial accelerating or lifting forces on the measuring apparatus. The shoe is surfaced with a test material such as rubber like that of the tread of a tyre for which it is desired to determine the coefficient of friction with respect to the surface to be tested. By suitable loading and calibration, an operator merely walks along pushing the apparatus with the shoe in contact with the surface to be tested. This produces rearward thrust along a longitudinal shaft slidably mounted in a housing to be nearly without friction. This thrust operates on a highly flexible diaphragm forming one wall of a hydraulic chamber filled with a liquid and communicating with a dial pressure gauge.

The invention is further described, by way of example, with reference to the accompanying drawings, in which:—

Fig. 1 is a side elevation, partly broken away, of an apparatus according to this invention;

Fig. 2 is a sectional view taken along the line 2-2 of Fig. 1;

Fig. 3 is a schematic diagram of the interior components of a gauge employed in the apparatus;

Fig. 4 is a sectional view of the gauge according to Fig. 3 showing the diamping disc therein; and

Fig. 5 is an elevation of a handle of the apparatus.

Referring now to Fig. 1, apparatus for measuring the skid or slip resistance of a surface 60 comprises a housing 1 formed from a block of aluminium having a longitudinal bore 2 therein. A longitudinal shaft 3, preferably of hardened steel is borne on ball bushings 4 and 4′ to slide freely in the fore and aft direction within the bore 2. A connector 5 is fixed to the shaft 3 at right angles thereto and is accommodated within a central aperture in the housing 1. The connector 5 is vertically oriented by a second hardened steel shaft 55 by a ball bushing 56 and carries at its lower end a friction shoe-carrying member 6 in the form of a shaft. The member 6 is secured to the connector 5 by a set screw 6′ so as to extend rearwardly therefrom at a downward angle and carries a friction shoe 8 which contacts the test surface 60. The shoe 8 is positioned relative to the connector 5 by a recoil spring 7 which urges the shoe along the member 6 towards the outer end thereof in a position to contact the surface under test. The member 6 is fitted with a pin 10 and a washer 10′ to limit movement of the shoe by the spring 7.

The shaft 3 is fixed to the connector 5 by a set screw 9 and is attached to a hydraulic piston 11 within an enlarged extension of the bore 2 by a set screw 9′. The piston 11 has an exposed end area forming one wall of a hydraulic chamber 14. This wall is completed by a highly flexible bellows or rolling type rubber diaphragm 12. The diaphragm 12 is attached to the piston 11 by a retaining seal 13 connected to the end of the piston 11. The diaphragm 12 and the seal 13 thus complete a movable wall of the pressure chamber 14 which has thereon a cap 15 secured to the housing 1 by a number of bolts 16 (one being shown) which compress the edge of the diaphragm 13 between the cap 15 and the housing 1. The chamber 14 communicates with a pressure channel 17 bored within the housing 1 by way of a bored channel 17′. At its opposite end the channel 17 has a hose 18 connected thereto by a nipple 18′ securing the hose to the housing 1. Flexible transparent plastics tubing may be employed as the hose 18, a plastics material having very little stretch being preferable to avoid excessive resilience in the hydraulic line. The hose 18 leads to a fitting 19 through a constriction in the form of an adjustable needle valve 20, to a pressure gauge 21. A measurement of instantaneous pressure in the chamber 14 is obtained, and this pressure varies with the longitudinal force on the diaphragm 12 exerted by the skid resistance of the surface under test as the shoe 8 is slid forward.

The skid resistance measuring apparatus advantageously has means for compensating for temperature changes so that it may be employed under variable conditions of sun, wind and rain. This requires that the hydraulic chamber and its connecting hose should have a volume adjustment according to temperature. It is, furthermore, desirable that the compensated hydrostatic pressure within the chamber be varied to facilitate measurement under certain conditions. As an example, it may be desirable that a skid resistance of a certain range of magnitude being repeatedly measured should have a fixed maximum value and a calibrated rate as the gauge 21 responds to increasing pressure as the shoe 8 is moved along the surface 60 under test. It may be desirable to statically load the pressure chamber to produce a desired zero gauge reading and, as the longitudinal force on the shaft 3 increases, a calibrated reading in a desired range proportional to the force on the shaft 3. It is also required that the pressure system be maintained full of liquid at all times.

Accordingly as shown in Fig. 2 the housing 1 contains a vertical bore 22, closed by a screw closure 22′ and connecting with the bore 17 and with a chamber 23. A compensator piston 24 is fitted in the chamber

23 and is sealed by O-rings 24'. The volume of the chamber 23 is varied by adjusting a screw 25, held within a plug 26 by a snap ring 27 screw threaded into the piston 24. Anticlockwise rotation of the screw 25 moves the piston 24 to the right thereby decreasing the volume of compensating chamber 23 to statically load the chamber 14 when the shaft 3 is at its forward limit of travel. An initial gauge reading a little below the expected test values serves to speed the response of the gauge when the damping is super-critical, clockwise rotation increases the volume of the chamber 23, as might be necessary to compensate for rising temperature and so keep the resting point of the gauge at the desired value. It will be evident that any adjustment of screw 25 produces a corresponding change in the dial reading of the gauge 21 under conditions of rest when the shaft 3 is at its forward limit of travel.

The housing 1 is provided with access openings for adjustment and assembly of the apparatus, which openings are closed during use by a ballast plug 28 and access plugs 29 and 29'. The connector 5 extends vertically below the housing and a sealing membrane 30 is fastened to the housing 1 by a retaining ring 30' (Fig. 2) and has an opening therethrough receiving a grommet 31 (Fig. 1) closely fitted around the member 6 in a manner to permit the connector 5 to move fore and aft without restraint by the flexible sealing membrane 30.

At the forward end of the housing 1 a pair of side panels 32 of rigid material constitute an extension of the housing and are secured thereto by screws 33 and 33' to support the forward end of the housing on a pivot 34, formed in the extension of a handle casting 35. The casting 35 receives a handle 36 and is borne on a pair of trolley wheels 37 by means of an axle 38 at which the front end of the housing is supported. The handle 36 and the casting 35 are offset to provide a handle extending backwardly past the rear end of the housing 1 while maintaining the pivot 34 essentially beneath the wheel axle 38. The wheels 37 may be of any simple commercial structure having thereon tyres of smooth tread. During use the extension of the handle casting 35 is substantially vertically below the axle 38. This extension is provided with an opening permitting the casting to pivot through a substantial arc between an adjustable eccentric spacer 39 and a stop portion 39' attached to the side panels 32. A grommet 40 receives the tube 18 and supports it adjacent to the fitting 19.

The gauge employed for measurement of the pressure within the chamber 14 may be one of several known types, such as bellows gauge, since the pressure employed will generally be well within the range of such gauges. Alternatively, a Bourdon gauge may be used as illustrated at 41 of Fig. 3. This gauge comprises an arcuate tube 41 carried on a base 42 connecting with a fitting 43 which is screwed on to the needle valve 20. The fitting 43 is supported in a projection 44 of the handle casting 35. A screw clamp 45 fixes the position of the fitting 43 within the projection 44. A set screw 46 secures the handle 36 within the casting 35 adjacent the projection 44.

The free end 47 of the Bourdon tube 41 adjustably engages a movement magnifying mechanism 50 which actuates a pointer 48 journalled in bearings 51 within a housing so as to move over a dial 49 of the gauge as shown in Figs. 3 and 4.

In the use of the skid resistance measuring apparatus illustrated by way of example, an operator moves along at a steady walking speed, preferably to test a substantial distance along a road surface. To avoid a tendency to develop resonant characteristics and oscillation of the pointer 48, a damping disc 52 is secured concentrically to the shaft carrying the pointer 48 and has a sufficient mass to average out or damp small rapid impulses tending to set the pointer 48 into vibration.

As shown in Fig. 5, the handle 36 extends rearwardly to a position above or behind the housing 1 but is further supplied with a handle extension 53 which has an adjustable elevation and is secured to the handle portion 36 by a clamping arrangement 54.

The piston 11, instead of being carried on the shaft 3 as described, may be carried on the auxiliary shaft 55 connected in this case to the connector 5. It is convenient to vary the weight of the housing 1 and thereby the pressure applied to the shoe 8 in contact with the surface 60 and for this purpose a ballast chamber 57 is supplied into which may be inserted ballast shot 58, this chamber being closed by the ballast plug 28.

The shoe 8 may take a number of shapes for friction measurement and may be faced with different materials according to the coefficient to be measured. To measure sliding friction between a wooden floor and objects placed thereon the shoe 8 would be faced with wood having a characteristic configuration and loading in accordance with the measurement to be made. To simulate a table leg having end grain exposed, the shoe would have a corresponding configuration on its face. For measuring the skid resistance of road surfaces a rubber facing is placed on the shoe 8 which is provided with a loading per square inch of contacting surface related to the loading of a vehicle wheel and may exhibit edge effects comparable to those of tyre treads normally employed in contact with the road surface. By experi-

ment it is found that a rubber faced metallic shoe of three to five inches width may be disposed with one edge riding against the surface 60 at a considerable angle such as 30° to simulate those conditions where the tyre tends to override successive humps and hollows of the road surface. Such a shoe is found to have considerable durability before the exposed edge is worn sufficiently to greatly change the friction as measured by the force required to move the shoe along under the specific loading selected. This durability depends obviously on the roughness of the surface and the hardness of the facing material on the shoe as well as on the specific loading. Rubber material of the type employed in tyres under a total loading on the shoe of four to seven pounds has a typical durability of 1500 feet without appreciable change in the measured skid resistance.

In highway testing it is desirable to measure skid resistance under adverse circumstances. Temperature and humidity have a bearing on the coefficients and upon the total skid resistance for a given loading. Adverse summer time conditions are approximated by first wetting down the surface and then performing a drag test thereover at normal walking speed of approximately three miles per hour. Since temperature is a variant somewhat affecting the results, but in a regular way, the temperature is normally noted and a correction therefor is made prior to the calculation of the resulting coefficient. The slope of the road surface also has a bearing and a correction therefor is made according to usual mechanical calculations involving the sine of the angle of inclination. Where the slope is appreciable, a change will also be apparent in the relative height of the gauge above the pressure chamber, and a correction proportional to the cosine of the angle with respect to the vertical may be made according to well known engineering practice. There is also a correction for the gauge height, but this is made in the pointer zero adjustment since it is constant.

A manually pushed trolley of the type illustrated undergoes acceleration increasing and decreasing with respect to the steady rate during each step of the operator. This causes a fluctuation in the pressure, but the constriction in the line by the needle valve 20 is effective to damp out this spurious effect.

The coefficient of friction measured may be expressed as $f=F/L$, where F is the force required to cause the shoe to slip on the surface and L is the load thereon in suitable units. The pressure in the chamber 14 resulting from the skid resistance F will be $F=A.p.$ where A is the effective area of the piston 11 and p is the pressure in the hydraulic system resulting from the force F. Obviously, these two equations combine to provide $f=p.A/L$ as a measure of the coefficient of friction or an index figure for skid resistance, calibrated in the most convenient units for the particular application. Exact calculation is simply made according to well known theory, for example, L may be measured on a conventional scale or balance by lifting the shoe 8 from the surface, the shaft 3 being horizontal, and fine tension line may be employed with a pulley and weight arrangement to measure F at which a particular scale reading is reached, calibrating the dial 49 with respect to movements of the pointer 48 for specific values of the force F. After the apparatus has been designed and assembled A is constant and known and enters into the gauge reading as a calibrated pressure. Since the loading factor is easily changed to provide a standardized calibration, it is convenient to change the load to provide appropriate dial divisions in terms of force F. This is readily done by increasing or decreasing the ballast loading in the chamber 57. For many purposes it is desirable to have a coefficient of friction reading in percentage points by selection of L or F to provide a ratio of unit at full scale deflection of pointer 48 and to calibrate the dial in terms of 0 to 100. Pressure in terms of p then has a correction factor applied as a dial zero setting since the actual pressure at the gauge 21 is not the pressure in the chamber 14 but takes into account elevation differences.

WHAT WE CLAIM IS:—

1. Apparatus for measuring the skid or slip resistance of a surface comprising a housing supported at one end for movement over said surface, a friction shoe movably mounted on the other end of said housing for frictionally engaging the surface, means for applying a force to the housing in the proximity of said surface for moving said housing, a hydraulic system including a mechanism for resisting movement of the friction shoe relatively to the housing and converting a frictional force applied to said shoe into a hydraulic pressure, and a gauge hydraulically connected to said system so as to be responsive to said hydraulic pressure therein.

2. Apparatus as claimed in claim 1 in which the means for applying a force to the housing comprises a trolley to which the housing is freely pivoted at an axis in the proximity of said surface when the trolley is being pushed, the friction shoe being spaced from the pivotal axis so that the weight of the housing can produce the reaction necessary to create said frictional force.

3. Apparatus as claimed in claim 2 in which the trolley is a two-wheeled hand

trolley whose wheels are rotatable about a common axis and in which said pivotal axis is substantially vertically below the wheel axis when the trolley is being pushed.

4. Apparatus as claimed in claim 1, 2 or 3 in which said mechanism comprises a shaft longitudinally displaceable in the housing, a fixture rigidly attached to said shaft, said friction shoe being attached to a portion of said fixture extending below the housing, and a hydraulic piston on said shaft and sealed to a pressure chamber to which the gauge is hydraulically connected.

5. Apparatus as claimed in claim 4 in which the piston is sealed to the pressure chamber by a rolling type diaphragm.

6. Apparatus as claimed in claim 5 in which said fixture is slidable along a second shaft fixed in the housing for steadying the fixture.

7. Apparatus as claimed in claim 1, 2 or 3 wherein said mechanism comprises a highly flexible diaphragm.

8. Apparatus as claimed in any of claims 1 to 7 wherein said gauge is a Bourdon gauge.

9. Apparatus as claimed in claim 8 in which an inertia disc is fixed to the pointer spindle of the Bourdon gauge for damping pointer oscillations.

10. Apparatus as claimed in any preceding claim in which said hydraulic system includes a hydraulic chamber of adjustable volume for compensating for temperature variations.

11. Apparatus as claimed in any preceding claim in which said gauge is connected to said hydraulic system through a restriction for averaging gauge readings over periods of pressure oscillations in said system.

12. Apparatus as claimed in any preceding claim including means for varying the load applied to said shoe.

13. Apparatus as claimed in any preceding claim in which said shoe has a rubber friction surface.

14. Apparatus constructed and adapted for measuring the skid or slip resistance of a surface substantially as herein described with reference to and as illustrated in the accompanying drawings.

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Chartered Patent Agents.

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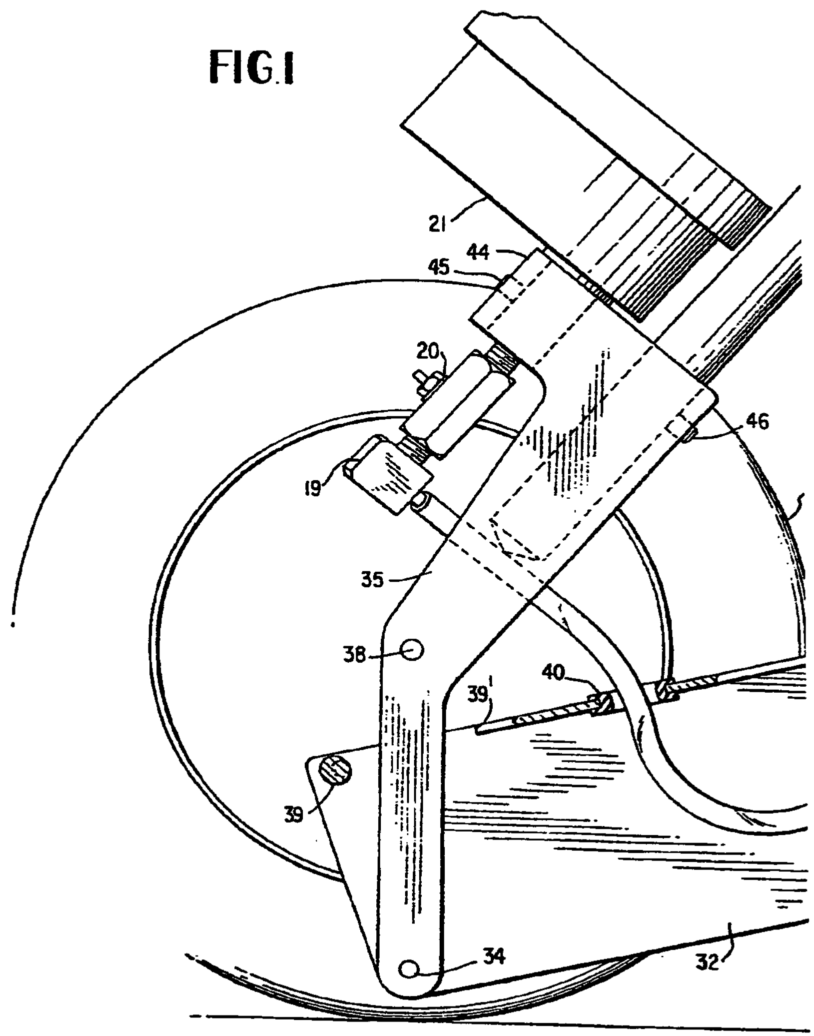
FIG.1



1090828 COMPLETE SPECIFICATION

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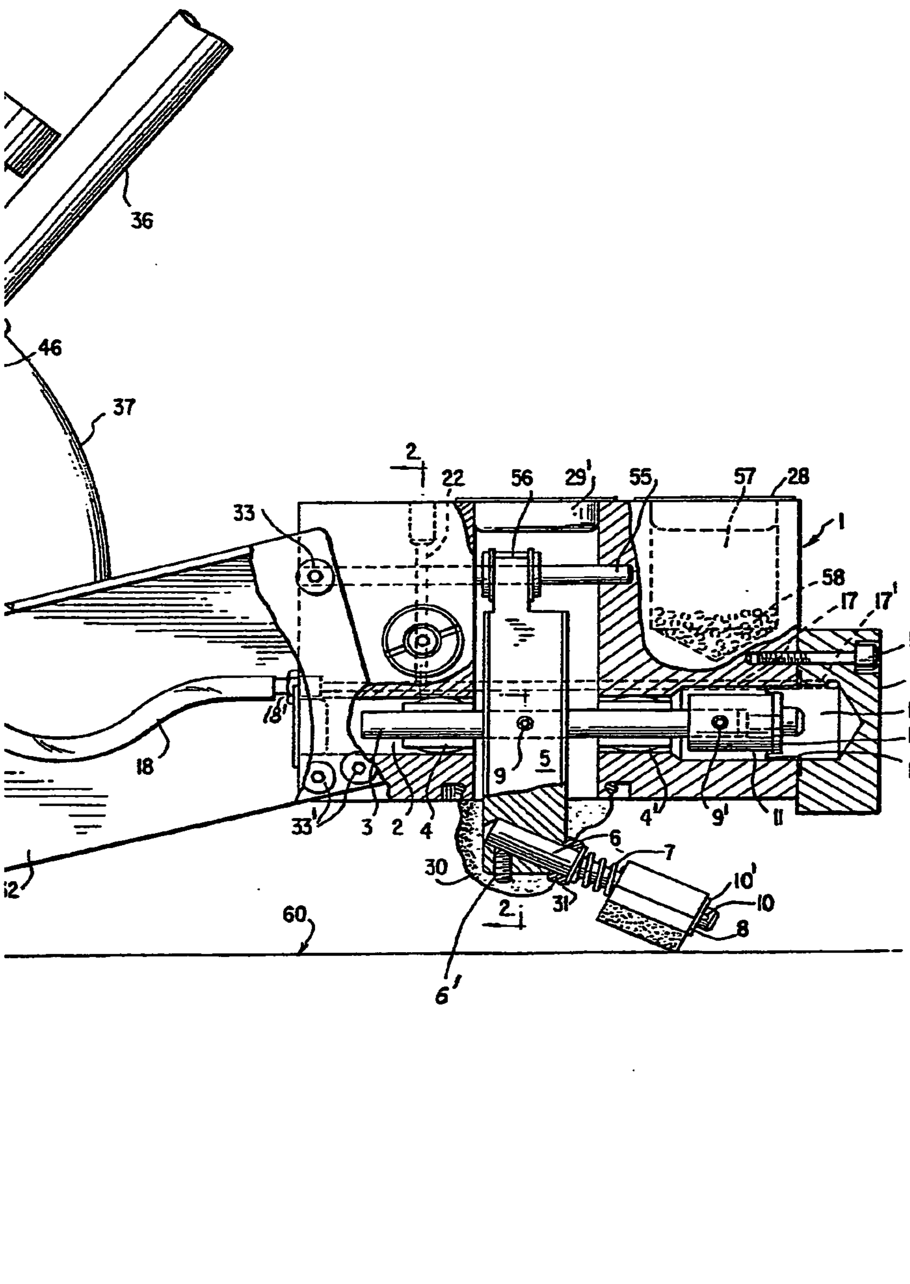

FIG.1

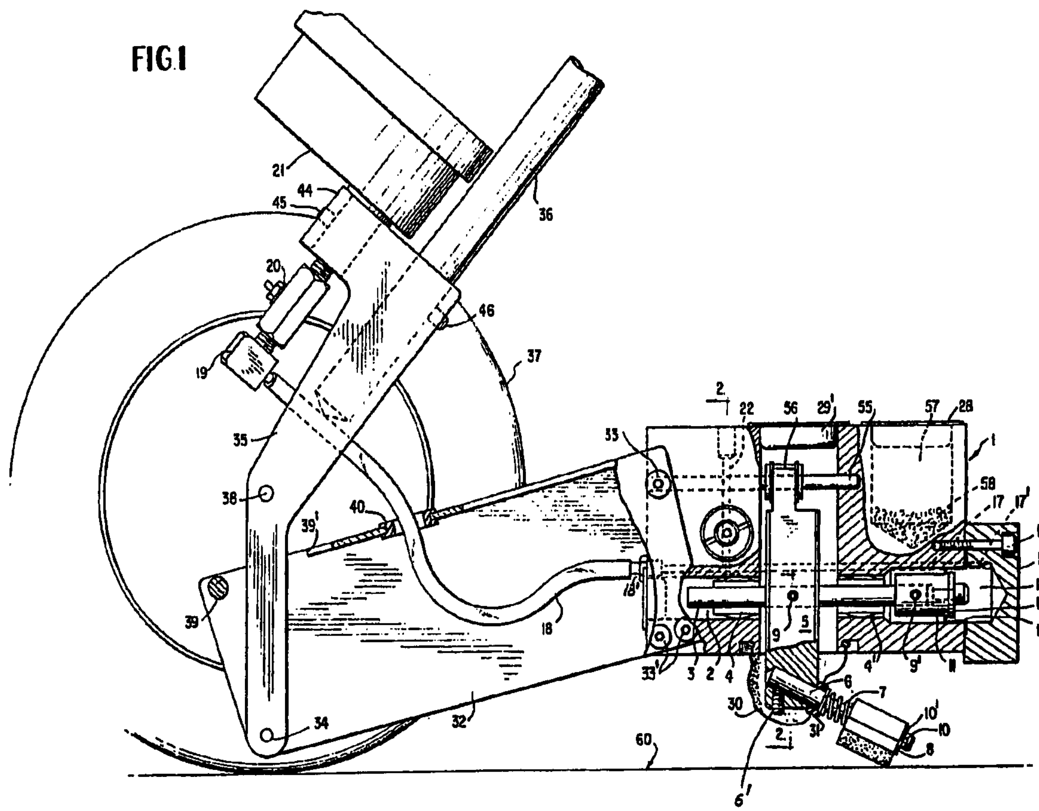
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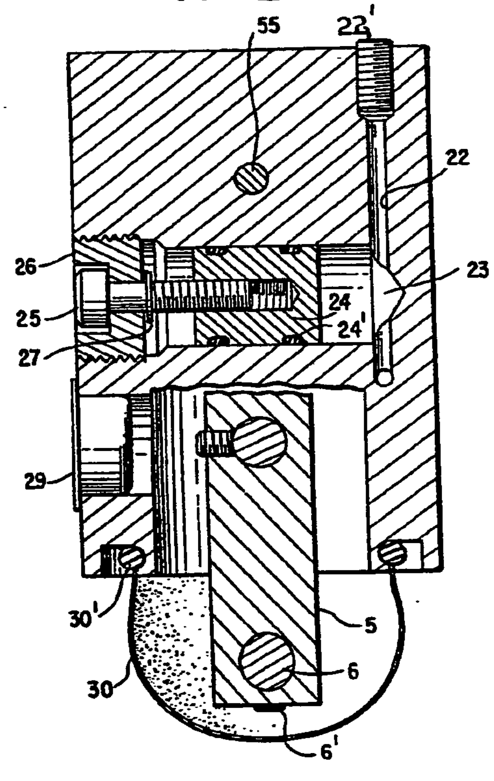
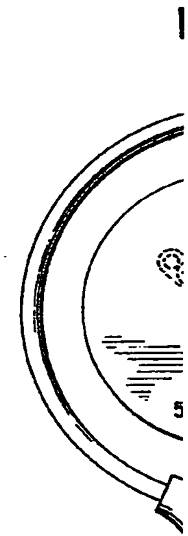
FIG.2



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Sheet 2

FIG.3

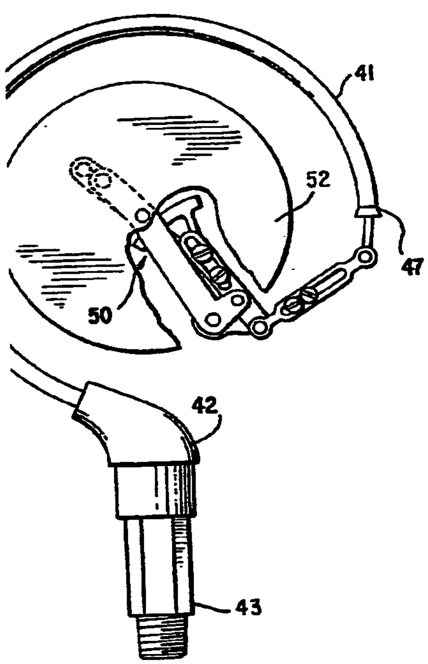


FIG.4

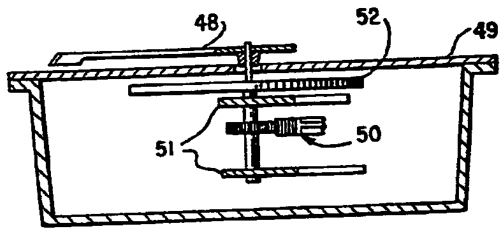


FIG.5

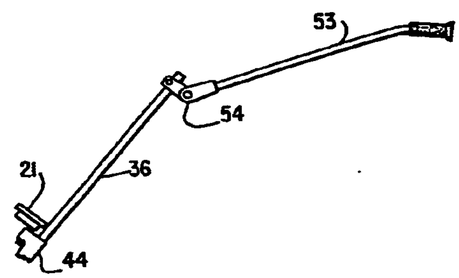

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FIG.2

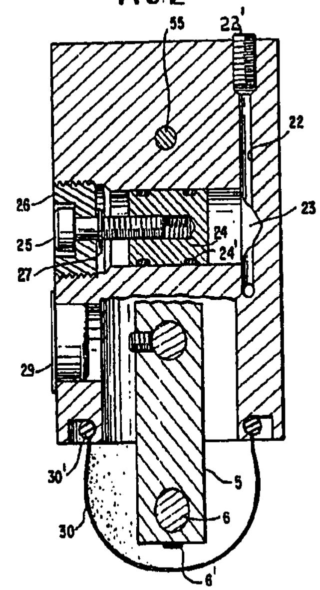



FIG.3

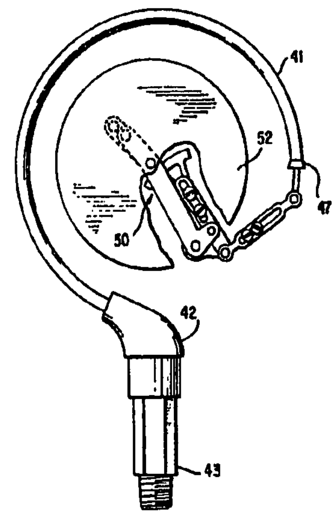



FIG.4

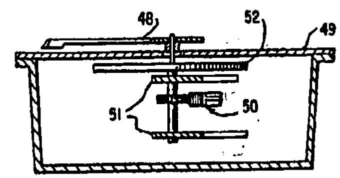
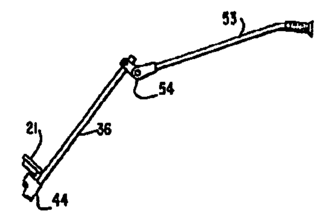



FIG.5



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